INFLATION IN THE PUFFERFISH *URANOSTOMA RICHEI* (TELEOSTEI: PLECTOGNATHI: LAGOCEPHALIDAE)

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ABSTRACT

Inflation was investigated in samples of pufferfish *Uranostoma richei* collected from Lyttelton Harbour, New Zealand between June 1969 and May 1970. Inflation was caused by water or air being swallowed and taken into a ventral diverticulum of the stomach, the subsequent expansion of which stretched the flexible outer skin causing the fish to assume a globular shape. There was a direct relationship between inflation capacity (ml of water) and fish length. Fish between 48 mm and 172 mm contained from 22 ml to 360 ml of water.

INTRODUCTION

The power of inflating the body as a means of defense is found in a number of lower vertebrates (see Hinsche 1928, Noble 1931). Several species of fish including some sharks will also inflate to some extent, but it is only in the Plectognathi that an elaborate inflatory mechanism has been developed (Breder and Clark 1947). In normal circumstances species of this group are more or less fish-shaped. However, when stressed they can greatly increase their size by swallowing large quantities of water or air. In some species this inflation is accompanied by the erection of skin spines (see Breder and Clark 1947, plate 13). All species in this swollen state become both difficult to seize and difficult to swallow which suggests that the mechanism is one of defense.

During a study on the biology of the pufferfish *Uranostoma richei* (Freminville, 1813) in Lyttelton Harbour, New Zealand (172°45'E, 43°37'S), fish in an inflated state were frequently encountered. This paper presents information on the inflatory mechanism and on the inflation capacity in relation to size of fish.

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MATERIALS AND METHODS

Between June 1969 and May 1970, numerous samples of pufferfish were obtained from Lyttelton Harbour (for sampling details, see Habib 1971). When boated the pufferfish were usually inflated (Fig. 1). The experience of being bumped about in the trawl may have stimulated inflation. Most fish were full of water although some contained a proportion of air. By careful selection, a size range of fish fully inflated with water was taken from one of the catches. Those which were partially inflated with air were rejected. They could be detected easily by holding them up to the light and noting the contained water level. Each fish was placed in a funnel over a measuring cylinder and forced to release its contained water. Volumes of water were measured and related to length and sex of fish. Appraisal of the results showed that there were no significant differences between the sexes and therefore all data were combined.

The inflatory mechanism was investigated by observing and stimulating live fish both in a tank on the sampling vessel and in a laboratory aquarium. A number of fish were also dissected.

RESULTS AND DISCUSSION

Dissection showed that during inflation, the water or air which is rapidly swallowed by the pufferfish passes into a ventral diverticulum of the stomach (as figured in Takai, Mizokami and Matsui 1959). As water is compressed into it, the diverticulum inflates and spreads both along the length of the fish and up around the sides to just above the pectoral fins. The very flexible outer skin expands from the internal pressure and a globular shape is assumed.

The anatomical components of the mechanism have been well described (Gabriel 1940). Briefly, the muscles of the first branchiostegal ray depress a pad covering the ceratohyals, thus expanding the mouth cavity and drawing in water or air. The elevation of the ceratohyals forces the fluid or gas into the diverticulum through a sphincter-like ring. Fluid is retained in the diverticulum by a strong oesophageal sphincter and by the pylorus. Opercular valves prevent leakage during the compression stroke and fluid is released through the mouth and opercula with the relaxation of oesophageal and opercular valves (for skeletal references see Awati and Bal 1932).

There was a direct relationship between inflation capacity and fish length (Fig. 2). Fish which ranged from 48 mm to 172 mm contained from 22 ml to 360 ml of water. A linear regression equation was fitted by the least squares method to the logarithms of inflation capacity and length of each fish sampled. The equation took the form:

$$\log I = -2.2503 + 2.1187 \log L$$

where I = inflation capacity (ml) and L = total fish length

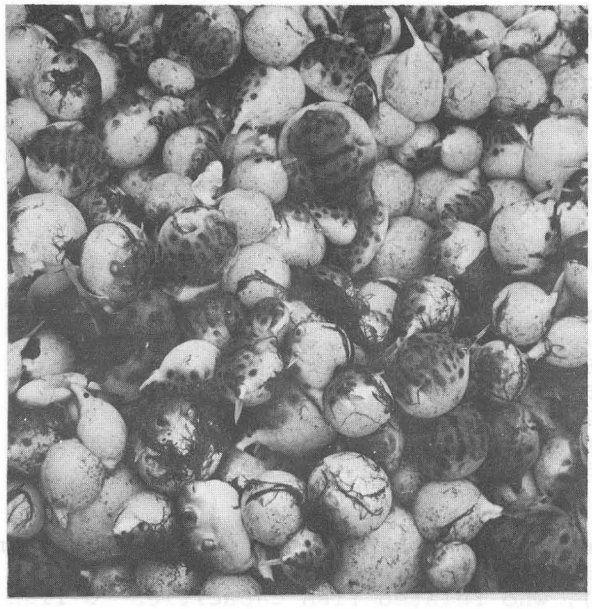

Fig. 1. A tank full of recently caught inflated pufferfish *Uranostoma richei*.

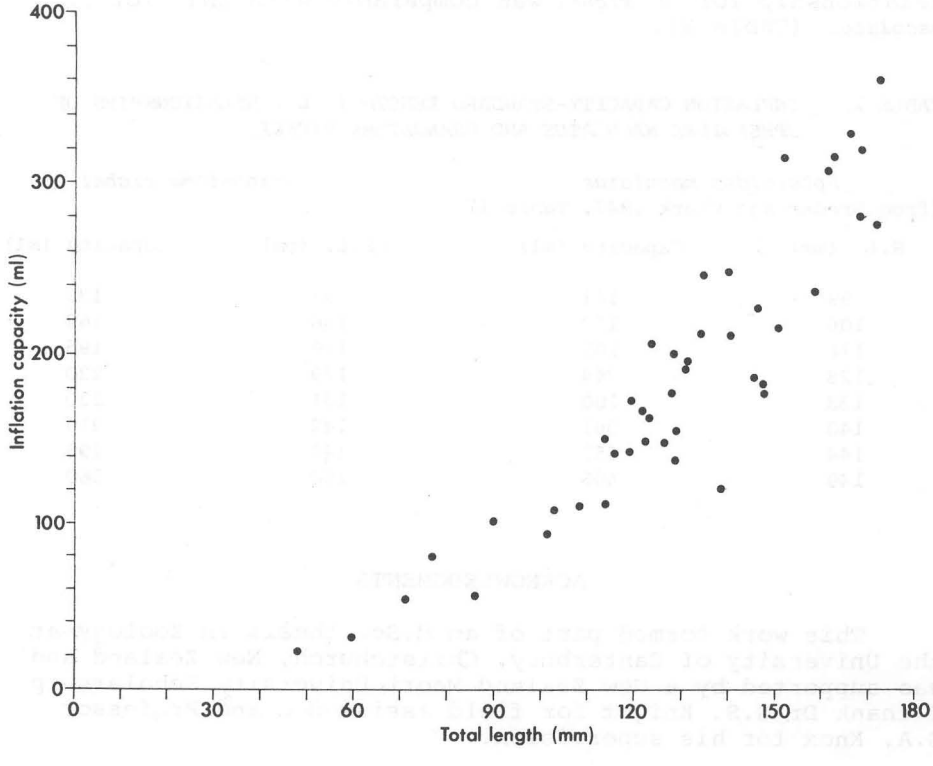

Fig. 2. Fish length-inflation capacity relationship for pufferfish collected from Lyttelton Harbour, New Zealand between June 1969 and May 1970.

(mm). The correlation coefficient for the two sets of variables was 0.961. The inflation capacity predicted for given lengths by the equation are listed in Table 1.

TABLE 1. EXPECTED INFLATION CAPACITY OF *URANOSTOMA RICHEI* OF GIVEN LENGTHS, DERIVED FROM THE EQUATION LOG I = -2.2503 + 2.1187 LOG L.

Length (mm)	Capacity (ml)	Length (mm)	Capacity (ml)
50	22.4	120	142.9
60	32.9	130	169.2
70	45.6	140	198.0
80	60.5	150	229.2
90	77.7	160	262.7
100	97.1	170	298.6
110	118.8		

A similar study on inflation capacity was carried out on the pufferfish *Spheroides maculatus* (Bloch and Schneider) by Breder and Clark (1947), who related fish capacities to fish standard length. The standard length-inflation capacity relationship for *U. richei* was comparable with that for *S. maculatus* (Table 2).

TABLE 2. INFLATION CAPACITY-STANDARD LENGTH (S.L.) RELATIONSHIPS OF *SPHEROIDES MACULATUS* AND *URANOSTOMA RICHEI*.

Spheroides maculatus (from Breder and Clark 1947, Table 1)		*Uranostoma richei*	
S.L. (mm)	Capacity (ml)	S.L. (mm)	Capacity (ml)
99	141	98	130
106	177	106	162
118	207	119	195
128	244	129	220
133	200	131	230
140	301	142	310
144	355	144	295
149	406	150	360

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